

JOURNAL OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

VOLUME XXII.

1.—CONTRIBUTIONS TO THE MINERALOGY OF WESTERN AUSTRALIA.

SERIES IX.

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Read: 13th August, 1935; Published: 16th March, 1936.

CONTENTS.

	Page
(1) Actinolite, Comet Vale.....	1
(2) Chlorite, Holleton, Ninghanboun Hills and Randalls.....	2
(3) Cobaltite and Erythrite, Ravensthorpe.....	4
(4) Fuchsite, Miloschite and Alexandrolite, Meekatharra.....	5
(5) Montebasite, Ravensthorpe and Ubini.....	8
(6) Muscovite, Wodgina.....	10
(7) Sillimanite, Toodyay and Clackline ; and Kyanite, Clackline.....	10
(8) Stibiotantalite, Greenbushes.....	14
(9) Zoisite, Jimblebah, Ninghanboun Hills, and Wongong Brook.....	16

With one text figure.

(1) ACTINOLITE, COMET VALE, CEN.

Between the town of Comet Vale and the shore of Lake Goongarrie the rock formation consists of Precambrian serpentine, succeeded to the east by amphibolite. In the steep gully of Tunnel Creek running down into the lake, the latter rock is traversed by quartz veins and shear and crush zones, all of which are auriferous, and many scheelite-bearing. The amphibole of the main rock mass is the dark green, strongly pleochroic, variety typical of the goldfields amphibolites. In the crush zones which have been impregnated with gold and scheelite, irregular patches of it have been altered into a variety of a pale grey-green colour. Small inclusions of the latter are to be seen in places in the auriferous reefs. Neither of these two amphiboles has been examined in detail.

On a dump on G.M.L. 4739 near the Lake View G.M., and close to the original source of the new mineral goongarrite, the Writer in 1933 found a third amphibole to be plentiful in hard satiny films in all the cracks in the quartz. It is characterised by an unusual bluish-grey colour (Ridgway 33^f to 45^d). The microscope shows that the masses are composed of roughly parallel groups of microscopic needles, which are practically colourless. They have a maximum extinction angle of 15°, which proves to be the angle between *c* and *Z*. The extreme refractive indices were found to be *N_g* 1.651, *N_p* 1.629. The specific gravity was 3.04.

In outward appearance the mineral resembles glaucophane ($H_2Na_2Mg_3Al_2Si_8O_{24}$) or abriachanite ($H_2Na_2Mg_3Fe_2Si_8O_{24}$), but analysis shows it to be an actinolite with only minor proportions of those molecules. The results obtained were:—

Actinolite, Comet Vale.

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO
Per cent. ...	56.80	.62	1.45	6.71	.23	19.75	11.24
Mols. ...	9457	61	91	934	32	4898	2004
	Na ₂ O	K ₂ O	H ₂ O+	H ₂ O—	TiO ₂	Total.	
Per cent. ...	.71	.12	2.58	.15	.12	100.48	
Mols. ...	115	13	1432	—	15		

Analyst: D. G. Murray.

From the analysis the following molecular percentages were calculated to be present in the "mixed crystal":—

Actinolite, $H_2Ca_2(Mg, Fe)_5Si_8O_{24}$	... ..	89.5 per cent.
Abriachanite, $H_2Na_2Mg_3Fe_2Si_8O_{24}$	... ..	6.3 ..
Glaucophane, $H_2Na_2Mg_3Al_2Si_8O_{24}$	... ..	4.2 ..

(2) CHLORITE, HOLLETON AND NINGHANBOUN HILLS, S.W., AND RANDALLS, CEN.

The Chlorite Group embraces a number of mineral species having the general formula $H_4R_3Si_2O_9 + H_4R_2R_2SiO_9$. In this formula, with certain rare exceptions,* *R''* is Mg or Fe'', and *R'''* is Fe''' or Al, and six end members are therefore theoretically possible, viz.:—

Antigorite, $H_4Mg_3Si_2O_9$	Ferroantigorite, $H_4Fe_3Si_2O_9$
Amesite, $H_4Mg_2Al_2SiO_9$	Daphnite, $H_4Fe_2Al_2SiO_9$
Magnesiocronstedtite, $H_4Mg_2Fe_2SiO_9$	Cronstedtite, $H_4Fe_2Fe_2SiO_9$

Intermediate co-crystallisations are only varieties of these six species, with chemical and physical properties following continuous smooth curves between the end members. In spite of these fundamental facts various authors, mainly petrologists, have burdened the literature with well over seventy unrelated names of chlorites, mainly on the strength of minute dif-

* In Kaemmererite *R'''* is partly Cr, and in Nepouite *R''* is mainly Ni.

ferences in optical properties, due, as in so many other isomorphous series, to varying degrees of isomorphous replacement, which in the majority of cases, are certainly not specific, nor even sub-specific. Winchell shows for example that the slightly positive optical character of certain chlorites changes by slow gradations through zero point to slightly negative with increase in proportion of iron-bearing molecules, and that the crossing point is not quite coincident with the chemically critical point, viz., the 50/50 per cent. proportions of the two end components⁽¹⁾. It follows that a least fifty of the names now appearing in the literature are redundant.

Up to the present, except for brief petrological descriptions in the publications of the Geological Survey, no details have been available regarding any West Australian chlorites. The following data have been elucidated recently.

Corundophilite, Holleton.

The Holleton chlorite is a slate green (near Ridgway 33¹k) mineral, forming lenses of very coarse plates up to 1 cm. in diameter, partly in radiating groups, in a massive chlorite rock of finer grain. The rock is part of the Archaean greenstone complex. No corundum is associated with it. The analysis given is that of the coarse platy mineral, which, when carefully handpicked, was entirely free from intergrowths or signs of weathering. The laminae are somewhat brittle, and under the microscope give a biaxial figure with 2E about 30°, and positive sign. Ng, 1.590, Np, 1.582. X and Y, bottle green; Z, colourless. The properties determined are all typical of this variety of amesite.

Analyses of West Australian Chlorites.

Species ...	...	...	Amesite	Amesite	Daphnite
Variety	...	...	Corundophilite	Clinochlore	Normal
Locality	...	...	Holleton	Ninghanboun	Randalls
SiO ₂	...	...	28.08	32.40	23.43
Al ₂ O ₃	...	...	22.16	19.17	18.21
Fe ₂ O ₃	...	...	1.46	2.36	4.49
FeO	...	...	9.56	4.04	36.30
MnO	...	...	.04	Nil	trace
NiO	...	...	Nil	.32	Nil
MgO	...	...	26.54	27.62	5.41
CaO, Na ₂ O	...	...	Nil	Nil	Nil
K ₂ O	...	...	.04	Nil	Nil
H ₂ O+	...	...	12.66	12.21	12.15
H ₂ O—	...	...	.26	1.56	trace
TiO ₂	...	...	Nil	.17	Nil
Total	...	...	100.80	99.85	99.99
G	...	...	2.80	2.69	3.14
Analysts	...	...	D. G. Murray	D. G. Murray	E. S. Simpson

The varietal names, in the case of the first two, were arrived at by determining the approximate proportions present of the pure molecules antigorite, amesite, ferroantigorite and daphnite or cronstedtite, and comparing them with the table and graph given by Winchell⁽²⁾.

Clinochlore, Ninghanboun Hills.

This mineral, collected at the extreme eastern end of Ninghanboun Hills, is in bunches of large plates in the outcrop of talkicised amphibolite. The hexagonal crystals are 1 to 5 cm. in diameter, and are mostly arranged in radiating spherulitic aggregates. It is slightly weathered in places. Some of the freshest mineral of 3 cm. diameter was analysed; it was of a dark greyish-green colour.

Incipient weathering, involving a change of FeO to Fe₂O₃, is indicated by a yellowish tinge in some other specimens. The colours are impossible to match with certainty against Ridgway's standards owing to the bright micaceous lustre of the mineral, but they are near 29ⁱ for the fresh mineral, and 25^k for that which is slightly weathered.

The results of the analysis are given in the table. A second specimen of the slightly smaller plates (1.5 cm. diameter) was found to contain FeO, 4.46 and total H₂O 13.78, as against 4.04 and 13.77 for the large plates.

Under the microscope the analysed mineral was almost colourless and biaxial, with a rather small optic axial angle, and positive sign. The composition and physical properties agree with those recorded for clinochlore.

Daphnite, Randalls.

In the Santa Clause G.M. at Randalls there are dense masses of greenish-black (R.33¹) microscaly chlorite, impregnated with crystals of arsenopyrite, the whole being slightly auriferous. Sufficient of the chlorite was separated cleanly with CH₂I₂ to enable an analysis to be made with the results given in the table. This shows the species to be daphnite, with slightly more magnesia than in the type mineral from Cornwall, which also is associated with arsenopyrite. Under the microscope it is appreciably birefringent, and negative in optical sign. Ng 1.661, N_p 1.656. X, greenish yellow, Y and Z, dark bottle green. The mineral is therefore typical in optical properties as well as in specific gravity and chemical composition.

References: (1) Wincheil, *Elements of Optical Mineralogy, Part II., 2nd Edit.*, p. 284.

(2) *Idem*, pp. 279, 280.

(3) COBALTITE AND ERYTHRITE, RAVENSTHORPE, S.W.

During a hurried visit to Ravensthorpe in 1934 it was found that these two minerals are plentiful in two gold mines not far from the town.

On the Golden Contact Prospecting Area, 1½ miles N.W. of the town, masses of small grains and imperfect octahedra of cobaltite are plentiful in quartz and chalcedony, together with thin films and stains of pale pink erythrite, and an undetermined yellowish ferric arsenate. A bulk sample of such ore taken from a depth of 30ft. and forming a 30-inch band on the wall of a clean quartz reef, assayed: Cobalt, 2.43 per cent; nickel, traces; gold, 28.88 dwts. per ton; silver, 8.5 dwts. per ton. Some of this ore was concentrated to yield as clean cobaltite as possible, and the concentrate then

analysed. After deducting 40 per cent. of insoluble quartz, and under one per cent. of FeAsO_4 , soluble in dilute HCl , the results recalculated to 100 per cent., were:—

Cobaltite, Ravensthorpe.

Co	Ni	Fe	As	S	Total
30.64	1.03	3.61	45.73	18.99	100.00

Analyst: H. P. Rowledge.

The molecular percentages of the concomitant molecules are:—

CoAsS	NiAsS	FeAsS	CoAs ₂
84.6	2.9	10.7	1.82

At the Bulldog G.M., also known as the Plantagenet G.M., about two miles N.E. of the town, beautiful specimens of erythrite were to be found in abundance in shallow workings on an auriferous vein consisting largely of quartz and chalcedony. The mineral is in broad films up to 2 mm. in thickness, on the many fracture planes in the vein. It is earthy in texture, and of a striking pink colour ranging from Ridgways 1'd, alizarine pink, to 71d, deep rose pink, rarely much darker, about 67i, aster purple.

In some specimens the origin of the erythrite can be traced to small granular bunches or scattered grains of cobaltite, which have been protected from oxidation by the dense siliceous matrix.

In both mines the matrix of the lodes appears to be a complex of Precambrian amphibolites of different types.

(4) FUCHSITE, MILOSCHITE AND ALEXANDROLITE,
MEEKATHARRA, MUR.

Fuchs site is the emerald green chromiferous variety of muscovite having the formula $\text{H}_2\text{K}(\text{Al,Cr})_3\text{Si}_3\text{O}_{12}$. Miloschite is the corresponding blue-green variety of kaolin $\text{H}_4(\text{Al,Cr})_2\text{Si}_2\text{O}_9$, and alexandrolite the similar bright green variety of halloysite, $\text{H}_4(\text{Al,Cr})_2\text{Si}_2\text{O}_9 \cdot 2\text{H}_2\text{O}$. The three minerals are often found in close association.

The most casual visitor to Meekatharra must be struck with the long line of bright green dumps stretching southward from the Wiluna railway line north-east of the town, past the State Battery to the summit of the ridge to the east of the town. An examination of the dumps, which are on still working or abandoned gold mines, shows that the strong colour is due to miloschite, alexandrolite and fuchs site, the first predominating. The material appears in every case to have been obtained in kaolinised rocks at depths down to about 100 feet. Below water level in the mine workings neither miloschite nor alexandrolite has been encountered, but in several mines there are bands of quartz-mesitite-fuchs site rock, which are highly carbonated phases of a large peridotite or pyroxenite intrusion, flanked by amphibolites and related rocks and intruded by ceratophyre dykes⁽¹⁾. All of these are Precambrian in age.

Typical specimens were collected by the Writer in 1932 from a number of the green dumps, and examined in the Laboratory with the following results:—

<i>Fuchsite, Miloschite and Alexandrolite, Meekatharra.</i>									
No. ...	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<i>Undecomposed by fuming sulphuric acid: Per cent. of whole sample.</i>									
Quartz ...	43.43	14.76	22.94	17.29	20.67	31.34	44.80	35.88	16.69
Other insol. ...	1.07	.36	.51	.44	.42	1.63	1.42	1.11	.79
<i>Decomposed by fuming sulphuric acid: Per cent. of decomposable material.*</i>									
K ₂ O ...	...	2.69	.07	.08	.05	.06	.15	.98	.86
Na ₂ O ...	...	.13	.14	.01	.01	.10	.11	.76	.63
H ₂ O+ ...	...	7.84	13.00	13.25	12.95	14.41	11.97	11.71	11.21
H ₂ O— ...	...	1.96	.57	3.29	5.09	5.49	5.87	9.71	10.76
Cr ₂ O ₃ ...	...	1.05	.68	.92	.87	1.37	1.60	1.46	1.15
Principal constituent	Fuchs.	Milosch.	Milosch.	Milosch.	Milosch.	Milosch.	{ Alexan. }	Alexan.	Alexan.
Second constituent ...	Milosch.	Fuchs.	—	Alexan.	Alexan.	Alexan.	{ Milosch. }	{ Milosch. }	—
<i>Colour (Ridgways Standards).</i>									
Dry ...	...	39 ^e	39 ^f	39 ^g	41 ^f	41 ^d	37 ^{ff} †	38 ^d †	38 ^d †
Wet ...	...	41 ^d	39 ^d	41 ^d	41 ^c	41 ^b	41 ^b	—	—

* Including separated silica.

† With inclusions of pale cream, nonchromiferous, clay and quartz.

‡ Two levigated moities of one specimen which in mass is 39' b both dry and wet.

The following are descriptions of the samples analysed, each being taken from a different mine dump. The mineral compositions given are those of the remnants after deducting quartz and insoluble:—

(1) Halcyon Group of mines. Granular, firmly coherent, slightly gneissic. Evidently leached quartz-fuchsite-mesitite rock. About 65 per cent. fuchsite, 30 per cent. miloschite.

(2) Pioneer Group. Dense, tough, fine grained. About 27 per cent. fuchsite, 58 per cent. miloschite, 15 per cent. alexandrolite.

(3) Pioneer Group. Fine soft homogeneous clay, slightly foliated. About 1 per cent. fuchsite, 95 per cent. miloschite.

(4) Halcyon Group. Slightly hard but brittle clay, somewhat foliated, many small ironstains. About 1 per cent. fuchsite, 74 per cent. miloschite, 25 per cent. alexandrolite.

(5) Halcyon Group. Similar to (4) but a little softer. Traces only of fuchsite. About 58 per cent. miloschite, 42 per cent. alexandrolite.

(6) Just N. of Wiluna Railway near 2m. post. Similar to (4). About 1 per cent. fuchsite, 55 per cent. miloschite, 45 per cent. alexandrolite.

(7) Halcyon Group. Anastomosing bands of blue-green clay in creamy white, porous, quartz rock. Probably leached quartz-fuchsite-mesitite rock. About 2 per cent. fuchsite, balance equal parts of miloschite and alexandrolite.

(8) (9) Halcyon Group. Rich green, much cracked, mass of waxy consistency, with embedded quartz fragments. The mass was crushed and levigated, all which sank through 5 inches of water in half a minute being rejected. The balance was divided into two grades, viz. (8) which sank in one minute, (9) which did not sink in one minute. Of these (9) is practically pure alexandrolite, contaminated only by about 1.5 per cent. fuchsite. (8) contains small percentages of both miloschite and fuchsite.

The approximate relative proportions of the three minerals present may be calculated from the analytical figures. Every one per cent of K_2O (including any relatively small proportion of Na_2O) represents 10 per cent. of fuchsite. Fuchsite contains 4% of H_2O+ ; miloschite, 14% H_2O+ and usually about 0.5% H_2O- , whilst alexandrolite contains 12% of H_2O+ and the same amount of H_2O- . After calculating from the alkalis the fuchsite present, the relative proportions of miloschite and alexandrolite can be calculated approximately from the figures for H_2O+ and H_2O- . The miloschite in (3) had G 2.67 and Nm 1.555, and was cryptocrystalline.

As to the origin of the minerals, the fuchsite is a metasomatic product of the basic igneous rock, due to invasion of the rock by magmatic potassium solutions charged with carbonic acid, a phenomenon often associated on our goldfields with the introduction of porphyry dykes and of gold into the Precambrian complex. From the frequent occurrence of this mineral with miloschite and alexandrolite at Meekatharra, and the occurrence of the three minerals along belts mapped by E. de C. Clarke (²) as occupied by carbonated amphibolites, pyroxenites and peridotites, the conclusion is drawn that fuchsite is the parent of the other two minerals. From the known occurrence in several places throughout the State (e.g. Toodyay and Menzies) of perfectly fresh fuchsite right at the surface, it appears that ordinary atmospheric weathering would not effect its transformation into clay minerals. In the Meekatharra area, however, many of the rocks, including some parts at least of the carbonated peridotite, are impregnated with pyrite and arsenopyrite, the weathering of which would give rise to sulphuric acid.

This would effect the leaching out of the mesitite, and also attack the fuchsite, dissolving out the alkali and transforming the chromiferous mica into the two chromiferous clays.

Reference: (1) 1916, E. de C. Clarke, *Geol. Surv. Bull. 68*. Text and maps.

(5) MONTEBRASITE, RAVENSTHORPE, S.W. AND UBINI, CEN.

Amblygonite (LiAlFPO_4), Montebbrasite (LiAlOHPO_4), and Fremontite (NaAlFPO_4) are very similar minerals, which occur under identical conditions, viz. in veins of granite pegmatite. They are completely isomorphous and capable of co-crystallising with one another in all proportions. In addition the molecule KAlFPO_4 is also isomorphous, but is unknown as an independent mineral, and is never present in more than small proportions in any known mineral. The correct name to be applied to any member of the group depends upon the relative atomic proportions of Li to Na, and of F to (OH), as determined by analysis.

Ravensthorpe.—As far back as 1911 the author detected a member of the group in material collected from the large pegmatite vein which crosses Cattlin Creek a little north-west of the town of Ravensthorpe. It has been referred to on several occasions (2) (3) under the provisional title of amblygonite, pending the necessary analysis to fix its classification definitely. The following figures have now been obtained on a representative specimen of the freshest material obtainable:—

Montebbrasite, Ravensthorpe.

P_2O_5	F	H_2O	Li_2O	Na_2O	K_2O	G	Ng	Np
47.44	2.72	4.57*	8.76	.60	.32	2.95	1.628	1.599

* By calculation.

The figures indicate the presence of the following molecules:—

LiAl(OH)PO_4	...	...	...	76.7	per cent.
LiAlFPO_4	...	...	...	19.1	„
NaAlFPO_4	...	...	...	3.1	„
KAlFPO_4	...	...	...	1.1	„

The correct name, therefore, for the mineral is Montebbrasite, the pure molecule of which preponderates over all others.

The largest specimen of it seen as yet is a mass about 9 x 5 x 5 cm. ($3\frac{1}{2}$ x 2 x 2 inches) associated with quartz, albite and bicoloured (green and pink) elbaite. On several sides this large mass is altered to a depth of several millimetres into a dull white, almost opaque, mineral, possibly variscite.

The clean mineral is greyish white in colour, with a pronounced basal cleavage reaching across the whole mass, and showing one twinning plane (101 ?) crossing it. A second cleavage (100) is less pronounced. Flakes under the microscope show a variable translucency, small areas being completely colourless and transparent; whilst the balance is more or less thickly crowded with minute grey inclusions, having no distinctive form. The clearest parts have a specific gravity of 2.98 to 3.01, but various other fragments yielded figures down to below 2.90 due probably to the presence of fluid inclusions. The material analysed was floated between 2.92 and 2.98. A refractive index determination on the clearest mineral yielded the figures Ng, 1.628; Np, 1.599.

Ubini.—Large masses of amblygonite were found here in a pegmatite vein many years ago, and have already been described (1) (2). The published analyses, one of which is quoted below, leave no doubt as to its specific identity.

In 1928 when the Writer visited the deposit he observed, in close association with the amblygonite, a few large masses resembling it in many ways but differing appreciably in colour and transparency. This second mineral resembled amblygonite in having one very pronounced cleavage, on the face of which traces of multiple twinning with irregular boundaries were to be seen. Furthermore it was translucent, had nearly the same density, and some of the masses were surrounded by an opaque white decomposition product similar to that seen at Ravensthorpe on montebbrasite, and occasionally at Ubini on amblygonite. The observed differences were that it was distinctly yellowish in tinge as compared with the pure white amblygonite, and it had a mottled appearance on the cleavage, due to a variation in translucency. The clearest parts were much more translucent than the amblygonite, the cloudy parts about the same as it.

Some of the freshest looking material was chosen from the centre of one of the masses for analysis. The figures are given below against "Montebbrasite?" with those of the amblygonite from the same vein for comparison.

	Al ₂ O ₃	Fe ₂ O ₃	Li ₂ O	Na ₂ O	K ₂ O	MgO	P ₂ O ₅
(1) <i>Montebbrasite</i> ? ...	35.90	.22	5.89	1.38	tr.	.02	44.36
(2) <i>Amblygonite</i> ...	34.71	.07	9.31	.78	<i>Nil</i>	<i>Nil</i>	48.01

	F	H ₂ O+	H ₂ O—	SiO ₂	Total	—O.F ₂	G
(1) <i>Montebbrasite</i> ? ...	4.04	8.93	.12	1.04*	101.90	1.70	2.90
(2) <i>Amblygonite</i> ...	6.95	2.70	tr.	<i>Nil</i>	102.53	2.92	3.02

* Includes combined SiO₂ 0.41. No Ca, Mn, Be, Ce or Y were detected in either.

Analysts: (1) D. G. Murray; (2) E. S. Simpson.

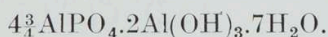
A determination of the Sp.gr. of a small fragment of the clearest portion of (1) gave 2.92. Much of the analysed material was less transparent and slightly lower in specific gravity.

The calculated molecules present are:—

LiAl(OH)PO ₄	23.25	} Montebbrasite.
LiAlFPO ₄	...	...	...	17.30
NaAlFPO ₄	...	...	...	4.57
AlPO ₄	19.12	} Ceruleolactite ?
Al(OH) ₃	...	...	...	8.20
H ₂ O	...	...	...	27.56
				100.00	

These figures are difficult to interpret. If the mineral is practically homogeneous, as the persistent cleavage and twinning suggest, it is an hitherto undescribed species having the complex formula H₃Li₅Al₈(OH)₅F₂(PO₄)₇.

If, however, the slight blotchiness in transparency and colour indicates an association of an alteration product, devoid of alkalis, with an original mineral of the Amblygonite Group, then the results may be interpreted as a mixture of original Montebbrasite, constituting 66% by weight, with Ceruleolactite, 34%. The latter mineral is credited with the formula 4AlPO₄.2Al(OH)₃.7H₂O, whilst the residue of the Ubini material, after subtracting montebbrasite, gives the ratios:—



- References: (1) 1911, E. S. Simpson, *Geol. Surv. W.A. An. Rept.*, 1910, p. 6.
 (2) 1912, E. S. Simpson, *Geol. Surv. W.A. An. Rept.*, 1911, p. 10.
 (3) 1919, E. S. Simpson, *Mining Handbook of W.A. Rare Metals*, p. 3.

(6) MUSCOVITE, WODGINA, N.W.

A very unusual type of muscovite has been found four miles S.E. of the township of Wodgina amongst the Archaean greenstone hills. It occurs on the surface in large angular boulders up to 6 inches (15 cm.) in diameter. Nothing is known of its immediate associations or genesis.

The mineral is devoid of all visible trace of scaly structure, being very dense, tough and subvitreous, and so compact that it carves well, takes an excellent polish, and when a dye solution is allowed to dry on a polished surface, it can be rubbed off quite easily, leaving no stain. Except for slight surface oxidation of the contained ferrous iron, it is perfectly homogeneous in texture and almost so in colour, the latter being between Ridgways 29ⁱ, pois green, and 25^k, lincoln green. It is translucent in layers up to 1 cm. thick. The hardness is 3½, distinctly higher than that of normal muscovite. It can be conveniently sawn with a hacksaw into firm blocks with sharp arrises, which show no tendency to chip. The various physical properties of the mineral make it admirably suited for carving into various small ornamental articles.

Under the microscope the homogeneity and unusual texture is confirmed. The masses appear to be of uniformly finely granular structure, with no trace of scaliness except along the disrupted edges of the section, where minute highly birefringent flakes are discernible.

Chemically the mineral is a typical muscovite. An analysis made for me by Mr. D. G. Murray shows:

Muscovite, Wodgina.

		SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO
Per cent.	...	46·01	37·08	·18	·16	·05	·16	·22
Mols.	...	7661	3637	11	22	7	40	39
		Na ₂ O	K ₂ O	H ₂ O+	H ₂ O—	TiO ₂	Total	G
Per cent.	...	·54	10·79	4·58	·12	<i>Nil</i>	99·89	2·84
Mols.	...	87	1145	2542	—	—	—	—

If the small amount of protoxides are calculated in turn to the two possible isomorphous molecules (1), H₂MgAl₄Si₂O₁₂ and (2), H₂Mg₂Al₂Si₃O₁₂, the ratios of the balance of the constituents are:

		H	K	Al	Si	O
(1)	...	2·01	1·02	2·84	3·08	11·94
(2)	...	2·02	1·00	2·92	3·04	11·97

Both of these are very close to the accepted formula for muscovite, viz. H₂KAl₃Si₃O₁₂.

Several types of compact cryptocrystalline muscovite have been described and given independent names. In the absence of type specimens of them it is impossible to correlate the Wodgina mineral with any of them with certainty. "Oncosine" is perhaps the nearest type. Some "Agalmatolite" also is of this nature.

(7) SILLIMANITE, TOODYAY AND CLACKLINE, S.W., AND KYANITE, CLACKLINE.

The first impression one gains of the Darling Range massif, and one supported by the maps and writings of earlier geologists, is that it consists entirely of massive and gneissic granite, with occasional greenstone dykes.

It is now certain, however, that there are considerable areas of Precambrian sediments included in it. The Writer has already recorded their occurrence throughout the length of the Chittering Valley ⁽³⁾ ⁽⁸⁾, and with Mr. J. E. Wells was the first to draw attention to them in the Jimperding Valley near Toodyay ⁽⁵⁾. The latter occurrence was later mapped in detail by Prof. E. de C. Clarke and his students, and described in brief by Clarke ⁽⁷⁾, and later in more detail by R. T. Prider ⁽⁹⁾.

Toodyay. No published record can be found of the occurrence of sillimanite in any of the metasediments in the vicinity of this town. Neither Clarke ⁽⁷⁾ nor Prider ⁽⁹⁾ makes any reference to its presence in the Jimperding Valley schists.

In the Writer's collection, however, are specimens illustrating its occurrence in six places in the district, three of them in the Jimperding Valley. The specimens are (1) A white kaolinised quartz-mica schist with many porphyroblasts of andalusite, and innumerable interbedded films composed of microscopic needles of sillimanite. Locality, 2 miles W.N.W. of Jimperding Hill.

(2) An ironstained quartz-muscovite-biotite schist with large porphyroblasts of andalusite, between two of which is a thick flake of white fibrous sillimanite, 50 x 30 x 5 mm. Locality, Block 3204, Jimperding Valley, South of Kowalyu-Katta.

(3) Quartz-biotite-muscovite schist, one specimen with a few large slabs of fibrous sillimanite, another with innumerable thin interbedded films of the same. Locality, North of Block 195, Jimperding Valley.

(4) Quartz-biotite-muscovite schist with a broad (3 cm.) plate of white fibrous sillimanite lying parallel to the foliation plane and enclosing small scales of biotite. Locality, collected by J. E. Wells 20 chains west of Key Farm, 2 m. S. of Toodyay.

(5) Biotite schist with thin plates of white fibrous sillimanite. Locality, 3 miles north-east of Toodyay.

(6) Small much weathered specimen of mica (biotite?) schist with silky appearance on cross fracture. This yields abundant micro-spicular sillimanite, 0.01 to 0.10 mm. in diameter, when treated with hydrofluoric acid. Locality, Perrin's prospecting area, Wongamine, 10 miles N.E. of Toodyay.

In each of these cases the identity of the mineral has been established by optical properties, supported when possible by chemical reactions and specific gravity determinations in methylene iodide.

Clackline. For over 30 years firebricks have been made at Clackline. The clay comes mostly from a large pit in what has been considered by most authorities to be an area of massive granite and granite gneiss, traversed by greenstone dykes, all the rock being completely kaolinised to a depth of at least 30 ft. in the clay pit. See for example F. R. Feldtmann ⁽²⁾ and A. G. D. Esson ⁽⁴⁾. E. de C. Clarke, however, published in 1930 ⁽⁷⁾ a sketch map showing a continuation of the Jimperding schists south-eastward through Clackline, but has no corresponding description in the text.

Last year two specimens of different clays from the brickworks were brought to me by Mr. C. S. Hunter (the proprietor) and Mr. J. E. Wells, and these appeared as if they might contain sillimanite. Laboratory tests by the Writer proved that in each case that mineral was indeed present to the extent of about 5 per cent. of the whole. In consequence of this, and the fact that Mr. H. Bowley had picked up a loose crystal of kyanite a little to the

north of the brickpit, the Writer visited the place early this year and carefully examined it for the presence of sillimanite and kyanite. None of the latter could be detected by eye though afterwards seen occasionally under the microscope. Sillimanite on the other hand was found to exist plentifully both in the main clay pit and within a radius of half a mile of it. This pit it should be noted is only 11 miles S.E. of the first find of andalusite schist at Jimperding, and approximately on the line of strike of the quartzites and andalusite-sillimanite schists existing there.

Careful examination of the faces of the main pit discloses that at least two-thirds of the kaolinised rock is distinctly foliated with vertical bedding, the remainder being massive. The latter appears to consist largely of kaolinised greenstone, but small tongues and veins of undoubted kaolinised pegmatite are visible in the foliated mass. The former consists of a mixture of kaolin, finely granular quartz, mica and sillimanite, with one band in which limonite pseudomorphs after almandine are easily recognisable. Typical specimens taken from the east side, centre, and west side of the main north face are distinctly seamed with thin plates and small lenticular "eyes" of almost pure sillimanite, which mineral constitutes from 5 to 10 per cent. of the whole mass.

The mineral was concentrated for detailed examination either by (1) puddling the coarsely broken ($\frac{1}{4}$ inch) clay until nothing but small fibrous lenses of sillimanite and associated quartz grains were left, or (2) treating a few grams of the finely powdered (60 mesh) clay with strong hydrofluoric acid, followed by strong hydrochloric or sulphuric acid, and then distilled water. The residue in both cases was examined under the microscope.

The mineral in every case occurs in fibrous lenses and thin silky plates of a pure white or pale buff colour, with the fibres parallel to the foliation of the rock. These aggregates easily break up into individual fibres ranging from 0.005 up to 0.100 mm. in diameter. The smaller ones are invariably perfectly straight, transparent, colourless rods. The larger ones often striated in the prism zone, and sometimes show a basal parting. No terminal prisms could be seen. Optically they are characterised by straight extinction, positive elongation, Ng. 1.680, Np. 1.659. Chemically they are typically resistant to hot strong HCl and HF. The specific gravity, when tested, was over 3.03.

A few small prisms of schorl and deep brown rutile, and rarely a small tabular crystal of kyanite, with typical extinction angle, cleavage, etc., were found in the sillimanite concentrates from one of the clays of the main pit.

On the west side of this pit a rather hard, but porous, and completely weathered, rock was found which appeared to be a local silicification of a softer rock. It was crowded with a network of thin films of finely fibrous, white sillimanite.

A concentrate from a single specimen of a strongly foliated micaceous clay in the small No. 2 Pit contained a few microscopic rods of sillimanite and tablets of kyanite. This pit is about 20 chains N. of the main pit.

In a costean a little further to the north-west is a very soft, highly micaceous clay with innumerable microscopic spicules of sillimanite (.005 — .01 mm. diam.) and occasional larger prisms up to several millimetres in length and 0.05 to 0.20 mm. diameter. Many of the flakes of bleached biotite are penetrated by needles of sillimanite. This frequent association of sillimanite with mica inclines one to believe that the so-called specular mica, said to be responsible for so many cases of silicosis, is in reality not mica but sillimanite.

A little to the west of the clay pit, the sediments are much more sandy, with bands in which small and large plates of white fibrous sillimanite are plainly visible. The chief constituents of these rocks are quartz, biotite, muscovite and sillimanite, some specimens being identical in macroscopic and microscopic appearance with certain rocks of the Chittering Valley. A sometimes partial, sometimes complete sericitisation of some of the sillimanite masses indicates a later stage of retrograde metamorphism.

This alteration of sillimanite into muscovite is brought about almost certainly in the zone of katabolism by the invasion of the meta-sediments by hot alkaline potash solutions from intrusive pegmatite or granite. It is not widely recognised in mineralogical literature, but has been observed on a large scale in India and recorded by J. A. Dunn (⁶), and again by A. Laeroix in Algeria (¹). Very perfect examples of it have been observed by the Writer in several places in the Chittering Valley close to intrusive granite.* At Clackline the evidence of this pseudomorphism is indisputable, the typical fibrous appearance, situation and form of the original sillimanite masses being perfectly retained.

From these observations it becomes clear that the greater part of the clay used in making firebrick at Clackline is a highly kaolinised biotite-sillimanite schist of the Chittering Precambrian series. Originally this rock was probably a highly glauconitic shale. That the kaolinised schist still carries some unaltered mica is indicated by the alkali contents of a sample from the east side of the pit, viz. K_2O , 1.80 per cent., Na_2O , 0.29 per cent.† Intrusive into it, and used with it in the brickworks, are at least three types of completely kaolinised igneous rocks. These are (1) granite pegmatite, (2) dolerite or epidiorite, (3) a chromium-bearing rock with little or no quartz, now a miloschite-bearing clay with occasional nodules of opal, but probably originally a hypersthene or serpentine, both of which species of rock are known as unweathered dykes within a radius of 15 miles of Clackline.

Probably from (2) is derived the vanadium which forms such conspicuous bright yellow films of potassium vanadate on the new bricks after they have been exposed to their first shower of rain. This often changes to a greenish-black vanado-vanadate by contact with organic dust.

- References:* (1) 1910, A. Laeroix, *Min. de la France*, 4, p. 679.
 (2) 1920, F. R. Feldtmann, *Geol. Surv. An. Rept.* for 1919, pp. 29, 30.
 (3) 1926, E. S. Simpson, *J. Roy. Soc. W.A.*, 12, pp. 62-66.
 (4) 1927, E. C. D. Esson, *Geol. Surv. An. Rept.* for 1926, pp. 13, 14.
 (5) 1928, E. S. Simpson, *J. Roy. Soc. W.A.*, 14, pp. 50, 51.
 (6) 1929, J. A. Dunn, *Mém. Geol. Surv. India*, 52, Pt. 2, pp. 150, 182, 201-2, 205, 207-9.
 (7) 1930, E. de C. Clarke, *Rept. Aust. and N.Z. Ass. Adv. Sci.*, 20, p. 167.
 (8) 1932, E. S. Simpson, *J. Roy. Soc. W.A.*, 18, pp. 66-7, pp. 75-82.
 (9) 1934, R. T. Prider, *J. Roy. Soc. W.A.*, 20, pp. 3-16.

* For example, near Block 780, Middle Chittering Valley.

† In addition there was 1.21 per cent. of NaCl, all the clays in the pit carrying a notable quantity of salt ranging from 0.5 per cent. upwards.

(8) STIBIOTANTALITE, GREENBUSHES, S.W.

Stibiotantalite is the name which was applied to a new mineral found at Greenbushes in 1893 by J. J. East and G. A. Goyder and described by them in the same and following years ⁽¹⁾ ⁽²⁾. The essential composition is SbTaO_4 . Stibiocolumbite, SbNbO_4 , and bismutotantalite, BiTaO_4 , are isomorphous compounds and, as well as existing as independent minerals, occur as co-crystallisations in stibiotantalite, the former in all proportions, the latter only in small amounts. Many descriptions have been given of the Greenbushes mineral, but most of them are only repetitions of the information published by East and Goyder, and of the further details published by the present Writer in 1907 ⁽³⁾.

The excuse for this note is an unpublished analysis and a description of a single crystal now available, with a few additional details regarding its occurrence.

The main source of the Greenbushes mineral has been the Enterprise M.L. 369, on the saddle between Floyds and Bunbury gullies, about a mile S.E. of the town, and the alluvium in these gullies below this lease. A little has also been found in Boronia gully near the Boronia M.L. 361, 2 miles N.W. of the town. Some has been found with tantalite and cassiterite in the Enterprise lode, a greisenised pegmatite, but the major quantity is in the tin bearing alluvium. In all probably well under one hundredweight of the mineral has been obtained, and most of it shipped away in parcels of tin ore or tantalum ore.

All the specimens obtained from the lode, and many of those from the alluvium, have been in the form of replacements of, or fissure fillings in, comparatively large pieces of tantalite. It thus appears that the genesis of the stibiotantalite has preceded that of the tantalite, the latter being formed by interaction between antimonial solutions and pre-existing tantalite in the later stages of pegmatite history. Veinlets are rare, and consist of honey-coloured translucent mineral, usually 1 mm. or less in thickness. Replacements are quite common and usually proceed from one side of the tantalite to an extent ranging from a thin shell only 1 mm. thick to an almost complete replacement of a mass several centimetres across. The advancing face of the antimony replacement is always uneven, and often ragged, whilst completely isolated inclusions of unaltered tantalite have frequently been observed in the stibiotantalite. This pseudomorphous stibiotantalite is usually very finely granular, dull grey or yellow in colour, and of low translucency.

In addition to the large alluvial pebbles of intergrowths of the iron and antimony compounds, the alluvial ground carries smaller pebbles, usually not over 5 mm. in diameter, of pure stibiotantalite. Many of these have the appearance of the replacing mineral just described, others are more or less translucent, and apparently consist of a single crystal individual. Owing to its comparative softness and brittleness, crystal faces are not preserved, only one crystal capable of orientation and measurement being known. Cleavage faces are more often apparent, and occasionally two adjacent crystal faces with worn boundaries.

Much of the alluvial mineral is translucent in thicknesses up to 4 or 5 mm. and some of it quite transparent when 1 mm. or rarely 2 mm. thick. The colour is usually some tint of pale yellow, sulphur, honey or lemon. Darker fragments grade towards cement grey on the one hand, and dark brown on the other. The mineral is anisotropic. In some pieces a distinct cleavage is to be seen, probably (001).

Specific gravities determined on a number of pebbles by the Writer were as follow:—

6.41, 6.75, 7.05, 7.05, 7.14, 7.17, 7.18, 7.26, 7.27, 7.29, 7.34, 7.35, 7.36, 7.41, 7.46, 7.48.

Goyder gave the range of specific gravity as 6.47 to 7.37. The highest figure must represent that of almost pure SbTaO_4 , the lower ones indicate increasing association with SbNbO_4 . The lighter specimens in some cases carry quartz inclusions. There does not appear to be any correlation between specific gravity and depth of colour. The heaviest fragment (G 7.48) was dark yellow, but two dark brown ones gave 7.26 and 7.35, and a pale sulphur yellow 7.41.

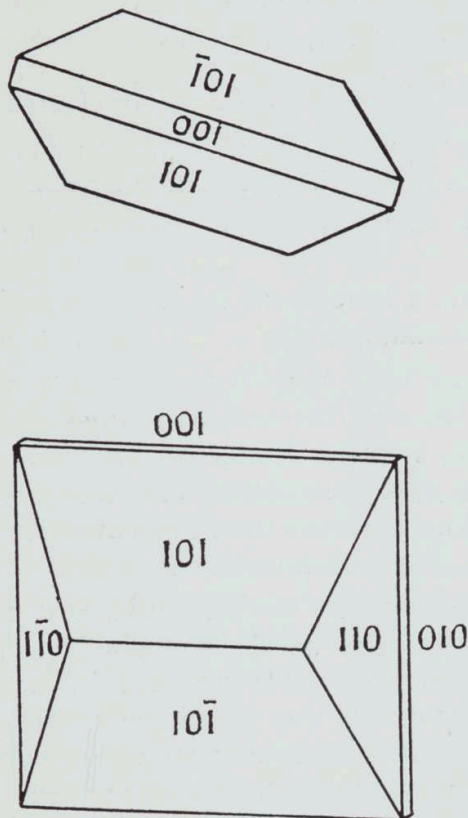


Fig. 1.—Crystal of Stibiotantalite, Greenbushes.

A broken crystal, the only large one seen, which measured 13 x 12 x 6 mm. had the form shown in the Fig. It was a combination of (010), (001), (110), (101). A number of smaller crystals, 1 to 3 mm. in diameter, were too imperfectly developed for their forms to be determined in the absence of complete crystallographic data for the mineral. The one which has been measured confirms the grouping of stibiotantalite with pucherite (BiVO_4).

In composition the Greenbushes mineral is found to consist mainly of SbTaO_4 , with minor variable amounts of SbNbO_4 , and usually under 2 per cent. of BiTaO_4 . The two analyses that have been made on pure mineral are:—

<i>Stibiotantalite, Greenbushes.</i>					
Ta_2O_5	...	...	51.13	57.29	
Nb_2O_5	...	...	7.56	1.79	
Sb_2O_3	...	...	40.23	40.64	
Bi_2O_3	...	...	.82	.30	
NiO	...	...	.08	Nil	
Fe_2O_3	...	...	trace	Nil	
			99.82	100.12	
G	...	...	7.37	7.345	

Analysts: G. A. Goyder E. S. Simpson.

The colour of the pebble analysed by the Writer was rather dark brown.

Mawson and Laby in 1904 examined specimens of the mineral for radioactivity, but found none. In 1911 W. G. Giles, an English chemist with considerable experience of the rare metals, wrote me that he had found in Greenbushes stibiotantalite decided traces of germanium.

- References:* (1) 1893-4, J. J. East, *Aust. Mining Stand.* 9, No. 233. *Trans. Aust. Inst. Min. Eng.* 1, pp. 139-142.
 (2) 1894, G. A. Goyder, *Trans. Roy. Soc. So. Aust.* 17, p. 127. *Rept. So. Aust. School of Mines*, pp. 163-5.
 (3) 1907, E. S. Simpson, *Aust. Ass. Adv. Sci.* 11, p. 452-5.

(9)—ZOISITE, JIMBLEBAH, N.W., NINGHANBOUN HILLS, AND WONGONG BROOK, S.W.

Only one analysis of a West Australian zoisite is on record, made by the Writer many years ago on specimens of saussuritized plagioclase collected at Sir Samuel(1).

Analyses of three other specimens are now available, one from Ninghanboun Hills being of unusual purity.

Jimblebah, N.W.—In 1927 the Writer found a number of small white angular boulders lying loose on the northern slope of the main eastern spur of the Hamersley Ranges between Jimblebah and Skeleton Creek. The rock formation here consists of Precambrian amphibolites intruded by large masses of serpentine. The boulders were not traced to their original matrix, which is probably some form of hornblende rock.

The boulders themselves are homogeneous and almost pure white in colour, except where ironstained on the surface from contact with the soil. They are hard and dense, and micro-granular in structure. Some of the cleanest material from the centre was taken for analysis, the results obtained being shown in the table. Microscopic examination reveals a finely granular (0.02 — 0.05 mm.) mixture of zoisite and albite with a little quartz and mica, the first predominating and in many cases exhibiting an anomalous bright "Prussian blue" interference colour, which according to Weinschenk is characteristic of clinozoisite. This blue colour is only to be seen in about one half of the grains, and is apparently only exhibited by sections of the mineral which are close to the optic axial plane. No prismatic sections were available to determine whether extinction was straight (zoisite) or oblique (clinzoisite). Calculation from the analysis given below indicates the presence of approximately—

Ferriferous zoisite	...	81.1	per cent.
Albite	... ..	15.3	"
Quartz	... ..	2.1	"
Muscovite	... ..	1.5	"

Ninghanboun Hills, S.W.—In 1930 the writer found a large pale pink and grey inclusion in the outcrop of a Precambrian hornblende rock near the eastern end of these hills. This inclusion, or segregation, which was several feet in length, was very hard and tough, with a microgranular structure. The pure pink parts of it graded imperceptibly into the greyer parts, whose colour appeared under the microscope to be due to a slight intergrowth of a darker coloured amphibole with preponderant zoisite. The pale pink masses were practically pure zoisite, having G 3.32 and 3.28. A fragment partly pink, partly grey, had G 3.27, one mostly grey, 3.14.

An analysis was made of the purest material with the results shown in the table. The figures taken as a whole show the following atomic ratios:—

	H	Ca	Al	Si	O
Theory for Zoisite ...	1	2	3	3	13
Ninghanboun mineral...	1.13	2.00	2.90	3.05	13.02

The material analysed was well over 95 per cent. pure, with small inclusions of felspar, amphibole, sphene (with occasional remnants of ilmenite), and zircon. Blue interference colours, not quite as bright as those observed in the Jimblebah mineral, were noticeable, but every grain showing a definite cleavage yielded a straight extinction, indicating zoisite and not clinozoisite. The granules were about double the size of those in the Jimblebah specimens.

Wongong Brook, S.W.—In sinking some trial shafts to test a proposed dam site in the valley of the Wongong Brook in the Darling Range, one of the many epidiorite dykes in the main granite mass was found to be studded with large porphyritic crystals and groups of crystals of a saussuritized plagioclase. These being light cream to greyish white in colour stand out most prominently against the almost black mass of the rock. In cross section they have mostly a fortification-like outline, consisting of straight lines joining a series of projecting and reentrant angles. They reach up to 10 cm. (4 inches) in diameter.

Microscopic examination of a thin slice of one of the masses reveals a typical saussurite, probably an altered labradorite, consisting of zoisite, albite, epidote, muscovite, quartz, chlorite and biotite. Those portions of the masses which are palest in colour are practically devoid of the last two, which are more abundant in the greyer portions. The zoisite in the section shows mostly bluish-grey interference tints, rarely brightening to greyish-blue.

An analysis was made of some of the lightest coloured portions, with the results given in the table. From this the mineral constitution is calculated to be—

	Zoisite	Epidote	Albite	Muscovite	Quartz	Chlorite Biotite traces
Per cent. ...	54	12	14	17	3	

Impure Zoisite.

No. ...	...	1	2	3
Locality	...	<i>Jimblebah</i>	<i>Ninghanboun</i>	<i>Wongong.</i>
SiO ₂ ...	...	45.59	39.69	45.66
Al ₂ O ₃ ...	...	29.29	29.95	29.65
Fe ₂ O ₃ ...	...	2.57	3.23	2.75
FeO ...	...	trace	.23	.59
MnO ...	...	<i>Nil</i>	.08	.07
MgO ...	...	<i>Nil</i>	.16	.65
CaO ...	...	18.66	23.88	15.15
Na ₂ O ...	...	1.82	.03	1.73
K ₂ O ...	...	.18	.22	2.01
H ₂ O+ ...	...	1.88	2.21	2.04
H ₂ O— ...	...	<i>Nil</i>	.05	.08
TiO ₂ ...	...	n.d.	.08	.06
CO ₂ ...	...	<i>Nil</i>	.03	<i>Nil</i>
Total ...	...	99.99	99.84	100.44
G ...	...	3.14	3.32	3.02

Analysts ...	D. G. Murray	H. P. Rowledge	W. W. Saw
Calcd. Zoisite ...	81%	99%	54%

ACKNOWLEDGMENTS.

The writer desires to express his thanks to Messrs. D. G. Murray, H. P. Rowledge and W. W. Saw, of the Staff of the Government Laboratory, for the valuable assistance they have rendered him by making analyses of several of the minerals described in this paper, and to Mr. J. E. Wells for specimens and field information.

Government Laboratory, Perth,
5th August, 1935.